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HIGH ABRASION OIL RESISTANT RUBBER COMPOUND FOR DMS COMBAT FOOTWEAR

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June 1976

UNITED STATES ARMY
NATICK RESEARCH AND DEVELOPMENT COMMAND
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Several high abrasion and oil resistant rubber soling compounds have been developed and evaluated to improve the durability of the heel and sole components of the all leather Direct Molded Sole (DMS) combat boot. One of the compounds evaluated is based on chlorosulfonated polyethylene type (Hypalon) elastomer and another on blends of nitrile-butadiene (NBR) /Hypalon/ cis-polybutadiene type rubbers. The compounds exhibited excellent properties exceeding the performance requirements of the then → next page

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#20 Abstract (continued)

standard all leather DMS combat footwear. The abrasive index requirements, for instance, of the standard compound have been exceeded by almost 200%.

Furthermore, evaluation of these compounds, which included processibility and producibility of end items under factory conditions, was also undertaken. Successful fabrication and evaluation of small-scale samples of boots incorporating these new rubber compounds resulted in a change of the abrasive index requirement of Military Specification MIL-B-43481 from 95 to 175. The factory produced DMS boots, which were evaluated for actual wear by the Marine Corps Recruiting Depot, San Diego, California, showed a significant increase in durability; but there is further room for improvement of the heels, particularly when worn under rigorous conditions encountered during recruit training periods.

PREFACE

The rubber soling compound used on the standard all leather Direct Molded Sole (DMS) combat boots has been developed to give a combination of satisfactory wear service and adequate low temperature traction on snow and ice. Reports received by this Command* from the various users of these boots and observations of worn boots shipped to these laboratories for analysis indicated that the sole and heel components of the combat boots and particularly the heels had worn excessively after unreasonably short periods of time. The poor appearance of the worn heel and the comments from the field became the motivation for initiating a development program directed toward increasing the wear life or durability of the all leather DMS boots.

It was believed that, through proper compounding, commercially available oil resistant rubbers could be used to provide tough, abrasion resistant long wearing sole and heel materials. The Rubber Technology Group of CEMEL then initiated a task program to develop such compounds. Initiation of this task was approved by the Deputy Scientific Director for Engineering, NLABS, in DF dated 25 May 1971. The development and evaluation of these high abrasive and oil resistant rubber compounds by the Rubber Technology Group were completed in 1973.

The author wishes to express his appreciation to E. I. DuPont de Nemours Co., Inc.; Naugatuck Chemical Division, Welco Research, Inc.; and to Standard Brands Chemical Industries for their assistance in compound development, to Douglas Swain and Robert Cargill of Footwear Technology Section, Clothing and Equipment Division for their advice and assistance; to Major J. Sabater, USMC, Representative Coordinator, NLABS, who was instrumental in arranging the wear tests at the Marine Corps Recruiting Depot, San Diego, California; and to Angus Wilson, Chief of the Rubber Technology Group for his assistance in initiating this development program.

*Formerly known as the U.S. Army Natick Laboratories (NLABS); present name: U. S. Army Natick Research and Development Command (NARADCOM).

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1. Introduction

The U.S. Army Natick Laboratories (NLABS) have a continuing program of developing or improving the quality of end items for Military use. An example is the development of two types of combat footwear. One of these is the tropical combat boot with a direct molded lug sole construction. The direct molded sole rubber compound which has been providing excellent wear performance in the field was based on a vinyl modified butadiene/nitrile type rubber. The second development is the all leather DMS combat boot with a rubber sole compound designed to provide the good wear of the compound in the tropical boot sole and heal, plus adequate traction on snow and ice. The requirements for this low temperature traction rubber compound, developed several years ago, were specified MIL-B-43481[1].

After the adoption of these requirements and a period of service use by the troops, reports of unsatisfactory wear of the soles and heels began to be received. An example was one concerning boots at the U.S. Army Armor Center, Fort Knox, Kentucky, which were withdrawn from use after 2 to 8 weeks of wear because the soles and particularly the heels, were wearing out at a rapid rate. The headquarters of the U.S. Army Armor Center reported this unsatisfactory wear performance and shipped samples of boots considered excessively worn at the heels to NLABS for examination and evaluation of the compound used. Abrasion tests on the heel compound were conducted and test results showed most of the heels met the original abrasive index of 80 then required by MIL-B-43481. Although 88% of the total number of heels tested passed the specification requirement, the appearance of the excessive wear on some of the heels in this case and reports of unsatisfactory wear from the Marine Corps and other users were matters of much concern to these Laboratories. It was evident that a need existed to improve the wear resistance of the standard compound, and a program to develop a high abraision resistant rubber sole compound with adequate low temperature traction was undertaken.

2. Exploratory Compounding

Exploratory compounding involves the designing of recipes, based on different types of rubber or rubber-like materials discriminately selected, such that resulting vulcanizates of the compounds give the desired properties.

[1]Military Specification
Boots, Combat, Men's, Leather, Black, Direct Molded Sole

In conducting the exploratory compounding, effort was directed toward obtaining an oil resistant rubber compound with improved high abrasion resistance; one which would provide the low temperature properties of the compound then in use. Thus, oil resistant type rubbers such as copolymers of butadiene/acrylonitrile (NBR), chloro-sulfonated polyethylene (Hypalon) or blends of NBR/Hypalon/Cis-polybutadiene or of blends of NBR/Cis-polybutadiene were utilized and explored. The compounding recipes with test results on properties used as criteria for selecting the desired compound are shown in Table 1.

A. Development of Hypalon Containing Compound for DMS Combat Footwear

Hypalon containing compounds have, for a long time, been known and recognized as possessing excellent abrasion resistant characteristics, and in the early development of the DMS boots[2], Hypalon containing compound had been explored, but its potential for DMS application was considered unsatisfactory because of difficulties in the milling and processing of compounds and in bonding the compound to leather boot uppers with the use of conventional attaching cement.

However, a new Hypalon containing compound developed by E.I. duPont de Nemours Co., Inc. for possible injection molding use was evaluated by the Rubber Technology Group for the all leather DMS combat footwear. That evaluation showed that the compound not only processed easily and met the specification requirements of the DMS footwear but far exceeded the abrasion requirement of the compound then used, by approximately 200%. Further, the compound also satisfied the molding and curing conditions imposed by the DMS process. The recipe for this compound is shown in Table 2.

Because of the excellent properties displayed by the Hypalon containing compound, consideration was then given to use this compound for the Army DMS footwear, and attempt was made to develop an improved vulcanizing cement for attaching the compounds to leather boot uppers.

B. Development of Nitrile Cement

During the development of a suitable cement, evaluations were made of several types of cements including a neoprene type prepared by E.I. duPont, two types prepared by Compo Industries, indentified as NN and H, for use in injection molding of the Hypalon compound, and several types formulated and prepared by the Rubber Technology Group, CE&MEL, identified here as Nitrile, H-A, and H-B. The compounding recipes of these experimental cements are shown in Tables 3 and 4, respectively, but the compounding recipes of NN, H, and neoprene types were not disclosed by the manufacturers.

[2] Javier, V.S., Low Temperature Traction Rubber Sole Compound for DMS Combat Footwear. Report 76-72-CM NLABS, Natick, MA - March 1967

These cements were evaluated by determining their bonding characteristics when they were experimentally used to bond Bandbury-mixed and Mill-mixed Hypalon compound to leather boot upper. The bandbury-mixed Hypalon compounds were obtained from Compo Industries in two different batches.

One batch, "old", was shelf-aged 4 to 8 days and the other batch, "new", was shelf-aged 24 to 36 hours. The bonding procedure involving the experimental cements used the standard procedure followed in the direct molded sole (DMS) process. Table 5 shows the evaluation test results on the experimental cements. Based on the test results, the NLABS Nitrile cement exhibited the best overall bond strength and was considered suitable for use. The NLABS H-A and H-B also exhibited satisfactory bond strengths. The NLABS Nitril cement compound was also found satisfactory for use with the high abrasion oil resistant DMS Compound based on the NBR/Hypalon/Cis-polybutadiene blends described below.

C. Development of Other High Abrasion Oil Resistant DMS Compounds

Several other rubber industries including Naugatuck Chemical Division of Uniroyal Co., Welco Research, Inc. and Standard Brands Chemical Industries worked on the development of an oil resistant high abrasion rubber compound for use in DMS footwear and submitted compounds to these laboratories for evaluation.

Naugatuck Chemicals submitted two compounds identified as I and J which were based on blends of NBR/Hypalon/Cis-polybutadiene. The uncured compound was prepared and mixed by the company and test sole samples were direct molded to boot uppers by the Rubber Technology Group at these laboratories. The compound recipes are shown in Table 6.

Welco Research, Inc. submitted a compound based on blends of NBR/Hypalon/Styrene-butadiene and the recipe is given in Table 7. The test samples as received, were in the form of finished boots with direct molded soles and heels.

The Standard Brands Chemical Industries also submitted test samples in the form of slabs prepared from two different compounds, the compound recipes of which are not shown.

Lastly, NLABS, as a result of exploratory compounding, also obtained a high quality compound designated as NB 34, the recipe listed in Table 1. This compound, based on experience gained from the evaluation of the various explored compounds, exhibited the best balance of properties in this series.

The compounding procedure in obtaining this desired compound was carried out with the conventional laboratory rubber mill for mixing the rubber ingredients and hydraulic press for curing the test specimens from the mill-mixed batch. The compound was also evaluated for processibility and producibility on the laboratory DMS vulcanizing equipment.

3. Test Evaluation Procedure

The compounds submitted to these laboratories for evaluation and the compound developed in-house, were evaluated for the following properties:

PROPERTIES TESTED	TEST METHODS
(a) Harness, Shore A @ Rm Temp. After 1 h @ -18°C (0°F) After Aging*	ASTM D2240
(b) Cut growth After aging*	ASTM D1052
(c) Abrasion Index Before aging After aging*	ASTM D1630
(d) Volume Swell After 48 h in 70/30 Isooctane/Toluene	ASTM D471
(e) Ozone cracking After 7 days in 50 pphm ozone @ 38°C (100°F)	ASTM D1149

* Aging in all cases was 70 hours @ 100°C. (212°F)

4. Test Results and Discussion

Test results on developed compounds are shown in Table 8. Based on test results, the E.I. duPont compound, based on chloro-sulfonated polyethylene base elastomer, exhibited a good balance of properties with the highest abrasive index properties, which far exceeded the then specified requirement. Other compounds such as compound I, submitted by Naugatuck, and NB 34 developed by NLABS, also showed properties meeting the requirements of MIL-B-43481 and exceeded the abrasive index requirement. Compound J, from Naugatuck, while exhibiting excellent abrasive index, could not satisfy the cutgrowth requirement.

The remaining compounds evaluated, although they satisfied all the specification requirements of MIL-B-43481, were considered as insufficiently improved in abrasion resistance.

The E.I. DuPont compound, the Naugatuck compound I, and also the NLABS compound, because of their superior laboratory abrasion qualities, were chosen as satisfactory for improving the abrasion requirement of MIL-B-43481, with subsequent improvement in wear of the all leather DMS combat footwear.

However, a decision was made to evaluate two of these compounds for producibility under factory conditions, and the two chosen were those developed by E.I. duPont and Naugatuck because of their superior abrasive resistance characteristics, in turn over the NLABS NB34. Arrangements were made with shoe manufacturers having DMS facilities to fabricate a quantity of all leather direct molded sole (DMS) combat footwear using the two newly developed rubber compounds for sole and heel components. One hundred pairs of size 10R boots with the Hypalon containing compound mixed at the B.F. Goodrich plant in Clarksville, Tenn., and one hundred pairs of size 9R boots with the blend of NBR/Hypalon/Cis-polybutadiene mixed by Naugatuck Chemical Division at their plant were successfully fabricated under factory conditions. Small scale samples of these boots were laboratory evaluated, and the results, which indicated a good improvement in wear potential, warranted a change of the abrasive index requirements of MIL-B-43481 from 95 to 175. The test results on the sole compounds used in the fabrication of the DMS boots, are shown in Table 9.

In order to have a confirmatory wear evaluation of the durability of the fabricated boots, this Laboratory was able to obtain the assistance of the Marine Corpos Recruiting Depot at San Diego in conducting wear tests on 100 pairs of these boots, 50 pairs with the compound based on blends of NBR/Hypalon/Cis-polybutadiene type rubbers and 50 pairs with the compound based on Hypalon. These experimental boots, which were wear tested by Marine Corps Recruits during their training, were crossmated with the then standard boots so that a comparison of the wear pattern could be obtained. In addition, a further evaluation was made by recording the original weight loss of the individual boots, and again the weight after the wear test, when the boots were returned to this Laboratory. Thus, the weight loss of the experimental was compared with the weight loss of the crossmated standard, by determining the ratio of the weight loss of one to the other.

The average weight loss ratio of the standard to that of the high abrasion compound, based on blends of NBR/Hypalon/Cis-polybutadiene, was found to be 2.1:1. This is in good agreement with the laboratory abrasive index of 250 and would indicate that this compound would sustain wear approximately 2 times better than the then standard compound. The average ratio of the weight loss on the standard to the weight loss on the high abrasion resistant compound based on Hypalon, was found to be 1.7:1, which is below what the laboratory abrasion result of 370 would lead one to expect, but shows the value of actual wear tests in conjunction with laboratory testing. This value would indicate that this Hypalon compound should be 1.7 times more durable in wear than the standard. Data on wear tests are shown in Tables 10 and 11.

Although wear test data and visual examination definitely indicated that boots with improved outsole and heel compound had better wear resistance than the boots with the standard compound, both the standard and the improved compounds, however, appeared to have worn away or rounded off around the heel edges, and the Marine Corps. Recruiting Depot stated that the heel compound used on the wear tested boot was not suitable for the Marine recruits in training (See Appendix A). This complaint prompted these laboratories to pursue compound development to further improve the heel-life of the present all leather combat footwear. Comments on wear test from the Commanding General of the Marine Corps Recruiting Depot for NLABS are included in Appendix A.

5. Conclusions:

A. Based on laboratory test results and producibility evaluation, these laboratories considered compounds based on Hypalon and blends of NBR/Hypalon/Cis-polybutadiene to have provided the desired and improved properties which were reflected in the change in abrasive index requirements from 95 to 175 in the revision of the specification.

B. On the basis of the actual wear test data, the boots with the high abrasion resistant rubber compound based on blends of NBR/Hypalon/Cis-polybutadiene exhibited wear resistance 2.1 times better than the boots with the standard compound, while the boots with the compound based on high abrasion Hypalon containing compound were 1.7 times better than the standard.

Table 1

Exploratory Compounding of Oil Resistant Rubber

Compounding Recipe

Ingredients	Parts by Weight per Hundred Parts Rubber					
	NB 16	NB 17	NB 18	NB 19	NB 20	NB 21
Paracril 18-80	70	85			70	90
Paracril BJLT			70	70		
Hypalon 40	15		15	15	15	
Taktene 1252	25	25	21	21	21	14
Stearic Acid	1	1	1	1	1	1
Zn O	3	3	3	3	3	3
Maglite D			1			
Hi Sil 233	50	50	45	45	45	50
EPC Black	3	3				
Philblack "O"			3	3	3	3
Plasticizer 3705	15	15	15	15	15	20
NBC	1	1	1	1	1	
Neozone A						1
Thermoflex A	2	2	1	1	2	2
Flexzone 3C	2	2	1	2	1	2
Sunproof JR	1	1	2	1	2	1
Carbowax 4000	1.5	1.5	1.5	1.5	1.5	1.5
Captax	0.75	0.75	0.5	0.5	0.5	0.5
Methyl Tuads	0.25	0.25	0.25	0.25	0.25	0.25
DOTG	0.5	0.5	0.25	0.25	0.25	0.25
Methazate	0.5	0.5	0.5	0.5	0.5	0.5
Sulfur	1.25	1.15	1.25	1.25	1.25	1.25
Cure: min/^{o}C	10/154	10/154	10/154	10/154	10/154	10/154
min/^{o}F	(10/310)	(10/310)	(10/310)	(10/310)	(10/310)	(10/310)
Cutgrowth after 50,000 flexes, % Samples aged 70 h/100^{o}C (212^{o}F)	500	150	500	400	500	250
Volume Swell in 70/30, Isooctane/ Toluene After 58h,%	61	63	42	42	51	40

Comments: Compounds not satisfactory. Volume swell or cutgrowth too high.

Table 1 (Continued)

Exploratory Compounding of Oil Resistant Rubber

Compounding Recipe

Ingredients	NB 22	NB 23	NB 24	NB 25
	Parts by Weight Per Hundred Parts Rubber			
Paracril BJLT	85			
Paracril 18-80		90	80	90
Taktene 1252	21	14	14	14
Stearic Acid	1	1	1	1
Zn O	5	5	5	5
Hi Sil 233	50	50	50	50
Philblack "O"	3	3	3	3
Plasticizer TP90B	20	20		
Dioctyl Adipate			20	10
Plasticizer 3705				10
Neozone A	1	1	1	1
Thermoflex A	2	2	2	2
Sunproof JR	1	1	1	1
Flexzone 3C	2	2	2	2
Carbowax 4000	1.5	1.5	1.5	1.5
Captax	0.5	0.5	0.5	0.5
DOTG	0.25	0.25	0.25	0.25
Methazate	0.5	0.5	0.5	0.5
Sulfur	1.25	1.25	1.25	0.25
Cure: min/°C	10/154	10/154	10/154	10/154
min/°F	(10/310)	(10/310)	(10/310)	(10/310)
Hardness, Shore A				
Rm Temp	63	60	64	64
After 1 h @-18°C (0°F)	78	68	78	78
Cutgrowth after 50,000 flexes,% Samples aged 70 h/100°C(212°F)	150	400	900	900
Abrasive Index				
Unaged	156			
Aged 70 h/100°C(212°F)	193			

Comment: NB 22 considered satisfactory; other compounds are unsatisfactory.

Table 1 (Continued)

Exploratory Compounding of Oil Resistant Rubber

Compounding Recipe

Ingredients	Parts by Weight Per Hundred Parts Rubber			
	NB 26	NB 27	NB 28	NB 29
Tylac 121A-LV	85	85	100	50
Paracril 18-80				50
Taktene 1252	21	21		14
Hi Sil 233	50	50	45	45
Philblack "O"	3	3	3	3
Octamine	1	1	1	1
Thermoflex A	2	2	2	2
Stearic Acid	1	1	1	1
Zn O	5	5	5	5
DOA	20			
Plasticizer 3705		20	20	20
Petrolatum			4	4
Sunproof JR	2	2	1	1
Flexzone 3C	2	2	2	2
Carbowax 4000	1.5	1.5	1.5	1.5
Altax	1.5	1.5		
Captax	-	-	-	-
Cumate	0.5	0.5		
Methyl Tuads	0.25	0.25	0.25	0.25
DOTG	0.25	0.25	0.25	0.25
Methazate			0.5	0.5
Sulfur	1.5	1.5	1.25	1.25
Cure: min/°C	10/154	10/154	10/154	10/154
min/°F	(10/310)	(10/310)	(10/310)	(10/310)
Hardness @ Rm Temp	75	75	61	55
@ -18°C(0°F)	90	90	78	70
Cutgrowth after 50,000 flexes % Samples aged, 70 h/100°C(212°F)	900	900	25	50
Abrasive Index (Unaged)	188	259	148	193

Comments: BN 29 considered satisfactory.

Table 1 (Continued)

Exploratory Compounding of Oil Resistant Rubber

Compounding Recipe

Ingredients	Parts by Weight Per Hundred Parts Rubber					
	NB 30	NB 31	NB 32	NB 33	NB 34	NB 35
Paracril BJLT	50	50				45
Paracril 18-80	50	50		42.5	45	--
Tylac 110B	--	--	85	42.5	--	--
Tylac 121A-LV	--	--	--	--	45	45
Taktene 1252	--	--	21	21	14	14
Hi Sil 233	50	50	50	50	45	45
Philblack "O"	3	3	3	3	3	3
Stearic Acid	1	1	1	1	1.5	1.5
Zn O	5	5	3	3	3	3
Plasticizer 3705	20		20	20	20	20
Plasticizer TP90B		20				
Neozone A	1	1				
Octamine			1	1	1	1
Thermoflex A	2	2	2	2	2	2
Sunproof JR	1	1	1	1	1	1
Flexzone 3C	2	2	2	2	2	2
Carbowax 4000	1.5	1.5	1	1	1.5	1.5
Captax	0.5	0.5	0.5	0.5	0.5	0.5
Methyl Tuads	0.25	0.25			0.25	0.25
Altax			0.25	0.25		
DOTG	0.25	0.25	0.25	0.25	0.25	0.25
Methazate	0.5	0.5	0.5	0.5	0.5	0.5
Sulfur	1.25	1.25	1.25	1.25	1.25	1.25
Cure: min/°C	10/154	10/154	10/154	10/154	10/154	10/154
min/°F	(10/310)	(10/310)	(10/310)	(10/310)	(10/310)	(310/310)
Hardness @ Rm Temp	55	55	58	58	58	60
Hardness @ -18°C(0°F)	70	68	75	72	72	75
Abrasive Index (original)	137	141	120	119	173	131
Aged: 70 h/100°C(212°F)	183	179	134	154	179	149
Cutgrowth, Aged, %	75	150	50	50	100	50

Comment: NB 34 exhibited the best balance of properties.

TABLE 2

DuPont Compounding Recipe

Ingredients	Parts Per Hundred Rubber
Hypalon 40	100
Mg 0	5
Stearic Acid	2
PER 200	5
Hi Sil 233	55
Arizona 208	20
Sundex 790	20
PE AC 617	2
SRF Black	2
Tetrone A	2
DOTG	0.4

TABLE 3

Nitrile Cement Compound Recipe

Masterbatch

Ingredients	Parts Per Hundred Rubber
Hycar 1001	100
Octamine	1.5
Zn 0	10
Philblack "0"	40
Stearic Acid	1
Cumar P25	15
Durez 12687	40
	207.5

Two Parts Cement	A	B
Masterbatch	103.7	103.7
Captax	2.5	-
Methazate	0.5	-
DOTG	0.5	-
Sulfur		2.5
MEK (Solvent)	323.0	320.0

TABLE 4

Experimental Cement Compound Recipe

Ingredients	Parts Per Hundred Rubber	
	H-A	H-B
Hypalon 40	100	100
Mg 0	5	5
Stearic Acid	2	2
PER 200	5	5
SRF Black	40	40
Sundex 790	20	20
PE AC 617	2	2
Tetrome A	2	2
DOTG	0.4	0.4
Durez 12687		40

	Cements	
	H-A	H-B
Mixed Batch (grams)	75	75
Solvent		
MEK	225	
Toluene		225

TABLE 5

Evaluation of Experimental Cement Compound for use with Hypalon Containing Compound

Types of Cement	Prepared by
NN	Compo Industries
H	" "
H-A	NLABS
H-B	"
NITRILE	"
Neoprene Type Cement	Du Pont de Nemours

Bond Strength Test Results

Number	Cements	Hypalon Batch	Bond Strength newtons	(lb)
1	*NLABS NITRILE*	*Mill-Mixed*	1468	(330)
2	" "	Banbury mixed (Old)	578	(130)
3	" H-B	Mill-mixed	979	(220)
4	" H-B	Banbury mixed (Old)	712	(160)
5	" Nitrile	Banbury mixed (New)	890	(220)
6	" H-B	Banbury mixed (New)	667	(150)
7	" H-A	Mill-mixed	890	(200)
8	" H-A	Banbury mixed (Old)	712	(160)
10	Compo NN	Banbury mixed (New)	578	(130)
11	NLABS Nitrile	Banbury mixed (New)	1156	(260)
12	Compo NN	Banbury mixed (New)	667	(150)
13	NLABS Nitrile	Banbury mixed (New)	1068	(240)
14	Du Pont Neoprene	Mill-Mixed	445	(100)
15	NLABS H-A	Banbury mixed (Old)	667	(150)
16	NLABS H-A	Banbury mixed (New)	756	(170)
17	Compo H	Banbury mixed (New)	712	(160)

TABLE 6

Naugatuck Chemicals Compound Recipe

Ingredients	Parts Per Hundred Rubber	
	Compound I	Compound J
Paracril BJLT	70	70
Hypalon 40	15	15
Taktene 1220	10	15
Black Masterbatch 1605	6	
HAF Black		5
Zn O	3	3
Stearic Acid	1	1
Flexzone 3C	3	3
Sunproof Jr	2	2
Hi Sil 215	45	45
Carbowax 4000	0.5	0.5
Maglite D	1.0	1.0
DOA	17.5	17.5
Sulfur, Spider	1.25	1.25
Altax	0.25	0.25
Captax	0.5	0.5
Methazate	0.75	0.75

TABLE 7

Welco Research, Inc. Compounding Recipe

Ingredients	Parts Per Hundred Rubber
Paracril BJLT	70
SBR 1502	10
Hypalon 40	15
Stearic Acid	1.0
Zn 0	5
Hi Sil 233	45
SBR 1614	7
Flexzone 3C	25
Sunproof Jr	3
DOA	15
Maglite D	1.0
Carbowax 4000	1.25
Captax	1.0
Altax	0.25
DOTG	0.25
Methazate	0.75
Sulfur	1.0

TABLE 8

Comparison Test Results on All Compounds

Properties Tested	Compound Sources: DuPont	Naugatuck Chem. Div.		Welco Research	STS Brands Chem. Industries		NLABS	Requirement of
		I	J		11612A	11612F	NB34	MIL-B-43481
Hardness, Shore A								
Unaged	65	60	62	70	62	60	58	65 ± 5
Aged 70 h/100°C (212°F)	68	65	66	78	64	62	65	Not more than 10 pts over orig.
After 1 h @-18°C(0°F)	80	75	78	85	80	78	72	Not more than 15 pts over orig.
Abrasive Index								
Unaged	233	175	251	98	118	123	173	95 min.
Aged 70 h/100°C(212°F)	660	255	315	138	104	155	179	95 min.
Cutgrowth after 50,000 flexes Aged 70 h/100°C(212°F)	0	200	400	228	200	100	100	200 max.
Vol. Swell, 70/30, Isooctane/Toluene After 46 hr @ Rm Temp, %	30	48	47	47	52	45	41	60 max.
Ozone, 50 ± 10 pphm, 38°C(100°F) After 7 days	No Crack	No Crack	No Crack	No Crack	No Crack	No Crack	No Crack	No sign of cracks

TABLE 9

Test Results on Factory Fabricated DMS Boots with High Abrasion Rubber Compound

Properties Tested	High Abrasion Compounds Hypalon Compound	High Abrasion Compounds Nitrile/Hypalon/ cis-polybutadiene	Requirements of
Bond Strength, newtons (lb)	867(195)	800(180)	600 (135 min.)
Hardness, Shore A			
Original	63	61	60 ± 5
After aging 70 h/100°C(212°F)	66	66	Shall not change more than 10 pts from original.
After 1 h @ -18°C(0°F)	78	77	Shall not exceed original by more than 15.
Abrasive Index			
Original	370	250	175 min.
After aging 70 h/100°C(212°F)	430	350	175 min.
Cutgrowth after 50,000 flexes, %			
After aging 70 h/100°C(212°F)	100	150	200 max.
Volume Swell after 46 h @ Room Temp in 70/30, Isooctane/ Toluene			
% Change	29	42	60 max.

TABLE 10

Evaluation of Wear Tested Boots w/High Abrasion Compound Based on Blends of Nitrile/Hypalon/Cis-Polybutadiene

EXP BOOTS	Weight (grams)			STD BOOTS				
Number	Orig	After Wear	Loss	Number	Orig	After Wear	Loss	Weight Loss Ratio STD/EXP
1A	797	777	20	1	770	732	38	1.9
2A	806	788	18	2	771	740	31	1.8
3A	789	771	18	3	787	756	31	1.7
4A	800	789	11	4	782	758	24	2.2
5A	805	771	35	5	788	714	74	2.1
6A	804	776	28	6	780	730	50	1.8
7A	783	773	10	7	782	753	29	2.9
8A	781	752	29	8	760	703	57	2.0
9A	798	770	28	9	746	700	46	1.6
10A	791	772	23	10	782	741	41	1.8
11A	791	774	17	11	782	752	30	1.8
12A	787	776	11	12	757	729	28	2.5
13A	781	757	24	13	752	692	60	2.5
14A	767	743	24	14	781	735	46	1.9
15A	757	727	30	15	781	715	66	2.2
16A	755	749	6	16	795	779	16	2.7
17A	810	798	12	17	832	810	22	1.8
18A	764	738	26	18	811	765	46	1.8
19A	775	753	22	19	833	787	46	2.1
20A	765	743	22	20	834	800	34	1.5
21A	750	729	21	21	814	775	39	1.9
22A	777	745	32	22	826	764	62	1.9
23A	751	726	25	23	836	780	56	2.2
24A	778	748	30	24	821	771	50	1.7
25A	785	780	5	25	822	808	14	2.8
26A	769	752	17	26	830	793	37	2.2
27A	765	734	31	27	819	763	56	1.8
28A	757	740	17	28	819	771	48	2.8
29A	778	760	18	29	830	800	30	1.7
30A	765	743	22	30	777	716	61	2.8
							Avg.	2.1/1

TABLE 11

Evaluation of Wear Tested Boots w/High Abrasion Compound Based on Hypalon Type Rubber

EXP BOOTS Number	Weight (gram) Orig	After Wear	Loss	STD BOOTS Number	Weight (grams) Orig	After Wear	Loss	Weight Loss Ratio STD/EXP
51A	864	843	21	51	824	793	31	1.5
52A	859	827	32	52	806	754	52	1.6
53A	870	827	43	53	789	720	69	1.6
54A	862	815	47	54	787	709	78	1.7
55A	839	830	9	55	803	786	17	1.9
56A	875	841	34	56	777	731	46	1.4
57A	871	827	44	57	784	727	57	1.6
58A	855	823	32	58	799	752	47	1.5
59A	840	827	13	59	792	756	27	2.1
60A	870	826	44	60	792	734	56	1.3
61A	862	845	17	61	775	735	40	2.4
62A	870	860	10	62	786	774	12	1.2
63A	875	840	35	63	815	757	58	1.7
64A	863	808	55	64	803	727	76	1.4
65A	838	818	20	65	783	853	30	1.5
66A	858	842	16	66	803	779	24	1.5
67A	883	868	17	67	840	808	32	1.9
68A	857	834	23	68	844	798	46	2.0
69A	872	844	28	69	845	804	41	1.5
70A	864	839	25	70	835	794	41	1.6
71A	895	877	18	71	836	798	38	2.1
72A	862	827	35	72	843	791	52	1.5
73A	865	821	44	73	842	756	86	2.0
74A	853	837	16	74	839	809	20	1.3
75A	874	853	21	75	851	821	30	1.4
76A	899	868	31	76	854	801	43	1.4
77A	841	797	44	77	843	776	67	1.5
78A	838	803	35	78	861	812	49	1.4
79A	852	826	24	79	841	796	45	1.9
80A	870	854	16	80	864	831	33	2.1
81A	894	877	20	81	841	800	41	2.1

Avg. 1.7/1

APPENDIX A

Report of Test from Marine Corps Recruit Depot, San Diego, California

NOTE: These pages of test report as reproduced are the true copies.

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43:HRK:mn
3690/10120
2 Feb 1973

From: Commanding General, Marine Corps Recruit Depot, San Diego, California 92140

To: Commanding General, Marine Corps. Development and Education Command, Quantico, Virginia 22134

Subj: Wear Test of Direct Molded Sole (DMS) Boot; report of

Ref: (a) CG, Dev Cen, MCDEC, Quant VA., ltr D091/REB:jfh Of 25 Aug 72
(b) Mil Spec f/Boots, Cbt, Men's, leather, black DMS MIL-B-43481B dtd 24 May 72

Incl: (1) Chronology of Events of the DMS Boot Wear Test
(2) Serialized Roster of DMS Test Boots Issue/Recovery dates
(3) Photograph of selected DMS Test Boots before test
(4) Photograph of selected DMS Test Boots after test

1. Reference (a), requested that this Command conduct an 11-week wear test of the DMS leather combat boots. Reference (b) contained the current military specifications for DMS boots manufactured with a sole and heel abrasive index of 175.

2. Information. The substance that forms the sole and heel of the DMS leather combat boot has demonstrated a lack of durability that can be documented in retrospect to 1969. As a result of numerous complaints by the Marine Corps Recruit Depots, especially San Diego, this Depot was selected to conduct a wear test of the soles and heels of 100 pairs of boots (sizes 9R and 10R). These boots were crossmated with 100 standard boots, and 100 boots with a new NER/Hypalon soling compounds. Twenty (20) pairs (sizes 9R and 9D) of the experimental lightweight boots with polyurethane foam soles and heels were also tested. These pairs of boots were not crossmated with standard boots because of the weight differential (6 - 8 ounces lighter per boot). The old abrasive index for compound in soles and heels of standard boots is 95; however, for test boots designated with the alpha character "A", it is believed to be 195. Reference (b) requires the abrasive index to be not less than 175. Recruit Training Regiment Series 2113 and 2117 (4 platoons per series) were issued test boots on 19 September 1972 and 2 October 1972, respectively. The boots were recovered on 6 and 13 December 1972, respectively. Series 2113 tested the boots for 78 days, while Series 2117 test lasted 72 days. The average period of the test for both series was 75 days. One hundred ten (110) test boots were recovered and shipped to U. S. Army Natick Laboratories.

43:HRK:mn
3690/10120

3. Concept/Purpose. The concept of the test was to issue to as many recruits in one or more series undergoing normal recruit training (80 day cycles) one pair of the test boots, and that the Private wear his set of test boots (right and left boot) no less than 50% of the time. The recruit allowance is two (2) pair of boots; however, only one (1) pair of test boots was issued to a Private so as to include the maximum number of recruits in the test. The purpose of the test was to determine if the soles, heels, and bonding materials used in the test items represent improvements over that of the standard DMS leather combat boot in terms of durability, reliability, and suitability for Marine Corps use.

4. Report of test.

a. Enclosures*(1) through (4) contain the chronology of the test, serialized roster of DMS test boots, issue/recovery dates, and photographs of certain test boots before and after the test. The total days tested for each pair of test boots is recorded in enclosure (2) and is derived by subtracting the Julian date in the column entitled "Date Out" from the date in column entitled "Date In".

b. As requested by reference (a) an evaluation by item (soles, heels, and bonding materials used in test items) in terms of the purpose of the test is as follows:

(1) Generally, the soles of boots with the new NBR/Hypalon and Hypalon soling compounds showed improved durability over their cross-mated standard boot; however, the heels did not and are not an improvement. The chevron design on the sole wore away in most cases resulting in some loss of traction; however, there was sufficient sole left to make it suitable. Since the conditions under which the boots were tested are abnormal (prolonged marching on hard surfaces) it is difficult to state whether or not boots with the improved compounds are suitable for regular Marines considering the varying degrees and types of usage; but the compounds in the heels of those boots tested are not suitable for recruits in training. Many heels were worn down 7/16 of an inch or more. The results of replacement of heels locally at a cost of $2.00 has been poor.

(2) All experimental lightweight boots with polyurethane foam soling failed in durability. They are unsuitable for Marine Corps. use at this time.

*Not included in report

43:HRK:mn
3690/10120

(a) The boots with the Panama Chevron design appear to have too little compound holding the metal support in the bottom of the boot. The metal support was protruding, or ready to in most test items (see enclosure (4), boot serial number's 38U and 40U). The Panama Chevron design held up reasonable well except for the heels.

(b) All of the boots with the polyurethane foam compound, regular chevron and lug design, cracked across the sole or showed signs of cracking. Most of the lugs wore close to the soles and heels, leaving very little material. See inclosure (4), boot serial numbers 13U, 5U and 10U.

(c) All the test recruits preferred the lightweight boots because of their reduced weight. One additional desirable feature of the foam soling is its cushioning and insulating effects.

(3) Bonding material. No boots with the standard abrasive index material, improved compounds or polyurethane foam soling separated from the uppers. Although this does not represent an improvement between crossmated pairs of boots, it is an improvement over past DMS boots which have separated due to poor bonding. The heels of many boots with standard material and improved compounds contained hairline cracks around a portion of the heel (about 2"). This condition is believed to be a bonding error. Enclosure (4), boot 27A and its mate, contains such an error. Such a condition is not an improvement, and is unacceptable.

5. Recommendations.

a. That a boot with an economically replaceable sole and heel be manufactured for initial issue (2 pairs) to recruits.

b. If the above is uneconomical, that a practical, durable, reliable, and inexpensive process be devised for the replacement of the heels of DMS Boots of recruits, and permanent personnel.

c. That this Command retest the lightweight boots with polyurethane foam soling compound when discrepancies previously noted (cracking and poor abrasion) have been corrected.

M. M. Blue
Chief of Staff

Copy to:
CMC (Codes AO4E and AX)
Natick Labs (Code AMXRE-CCT)
McLnO, Natick Labs
CG, MCRD, PISC

D-091/REB:jfh
March 1, 1973

FIRST ENCORSEMENT on Commanding General, Marine Corps Recruit Depot, San Diego, California 92140 ltr 43: HRK:mn 3690/10120 of 2 Feb 1973

From: Commanding General, Marine Corps Development and Education Command, Quantico, Virginia 22134
To: Commandant of the Marine Corps (Code AX), Headquarters, United States Marine Corps, Washington, D. C. 20380

Subj: Wear Test of Direct Molded Sole (DMS) Boot; report of

Ref: (c) CMC ltr AX/A04E-ras-31 10120 of 26 May 1972

1. Readdressed and forwarded as requested by paragraph 2. reference (c).

2. The following comments are provided concerning the recommendations contained in the basic correspondence:

a. The DMS Combat Boot is a DOD wide standardized item that was tested by the various armed services (including the U. S. Marine Corps) and recommended for adoption since the DMS boot represented a significant improvement over the old standard boot with replaceable soles and heels.

b. One of the major design features of the DMS boot was the elimination of the necessity of sole and heel replacement, thereby eliminating the need for costly field boot repair crews and associated equipment within the military services. In normal field use, the soles and heels of the DMS boot last the approximate serviceable life of the upper leather portion of the boot and accordingly, when the heels or soles are worn out, it's normally in the best interest of the economy to replace the boots. However, sole and heel replacement can be made by Marine Corpos Exchange Shoe repair shops at an approximate combined cost of $5.00 per pair.

c. As stated in paragraph 4.c. of reference (a), the 16 pairs of lightweight boots (referenced in paragraph 5.c. of the basis correspondence) may not be long wearing because they were strictly an experimental item, included to evaluate wear patterns, since a lightweight boot is an objective of future development. Although it is well recognized that a lightweight boot is a highly desired item for combat use, the developing agency has indicated that approximately five years of development effort and testing will be required prior to obtaining an item suitable for standardization.

D 091/RFB:jfh

Subj: Wear Test of Direct Molded Sole (DMS) Boot; report of

3. Based on information available it is apparent that problems associated with the durability of heels and soles of DMS boots at MCRD, San Diego, are attributed mainly to the following:

a. Prolonged marching on hard surfaces.

b. The technique of instructing recruits to march by commanding "Heels-Heels-Heels" during close order drill.

c. Limited break-in time for boots prior to initiation of vigorous training.

4. In essence, the wear life of a pair of boots by a Recruit, at MCRD, San Diego, compared to that of a Marine undergoing normal training within a Marine division, can be compared to the tread life of two identical sets of tires, one set being used for racing and the other set being used for conservative driving.

5. In view of recommendations contained in the basic correspondence and the information provided above, it is recommended that the U. S. Army Natick Laboratories be requested to continue developmental improvement programs to increase the wear life of the Direct Molded Sole (DMS) Combat Boot.

THOMAS E. MURPHREE
By direction

Copy to: (less basic correspondence)
CMC (Code A03E)
U. S. Army Natick Labs
CG, MCRD, San Diego, California
CG, MCRD, PICS
McLnO, U. S. Army Natick Labs

CHRONOLOGY OF EVENTS OF THE
DIRECT MOLDED SOLE (DMS) BOOT
WEAR TEST

Date (1972)	Event
1 Sep	MGySgt H. R. KLEMM, Jr., Depot Clothing Chief designated as MCRD, SD, DMS Boot Coordinator.
13 Sep	Received serialized test boots from W13G07, U. S. Army Natick Laboratory, Natick, Mass. 01760 as follows:

	Qty	Size	Nomenclature
	51	9R	Crossmated all leather DMS boots w/chevron outsole and heel design. (NER/Hypalon blend soling compound)
	49	10R	Crossmated all leather DMS boots w/chevron outsole and heel design. (New Hypalon soling compound)
	8	9D	The experimental all leather lightweight boots w/Panama Chevron outsole and heel design w/polyurethane foam soles were not with standard boots because of the weight differential (about 6 to 8 ounces lighter per boot).
	12	9R	The experimental all leather lightweight boots w/new lug and regular chevron outsole and heel design w/polyurethane foam soles were not crossmated with standard boots because of the weight differential (about 6 to 8 ounces lighter per boot).
TOTAL	120		

Note: The experimental polyurethane lightweight sole and heel boots are identified with a "U" in serial numbers. The boots with the higher abrasive compound (abrasive index believed to be 195) are identified with an "A" in one of the boots of the pair.

18 Sep (A.M.) Major J. SABATER, MCLnO, Natick Labs (Autovon 955-2279) visited Director, Services and Supply Division, and Director, Materiel Branch, Depot Clothing Officer and Test Boot Coordinator.

(P.M.) Liaison between Major SABATER, Major RESSMEYER RTR-S4, and MgySgt KLEMM for the purpose of coordinating test and designating test series and reporting dates. Test Series are 2113 (Plts 2113 - 2116) and 2117 (Plts 2117 - 2120).

ENCLOSURE (1)

Date (1972)	Event
19 Sep	Series 2113 issued 59 pair Test Boots at Building 221. Control data collected on form, Addendum #1, and later transcribed into cards.
25 Sep	Coordinator, Test Boot Project letter HRK:dbg 4730 of 25 Sep 1972 to S-4, RTR transmitted Test Boot Project instructions, Addendum #2, and Platoon Rosters of recruits with test boots in Series 2113.
2 Oct	Series 2117 issued 60 pair Test Boots at Building 221. One pair, size 9R, serial number 19-20A was not issued. Insufficient number of recruits wore that size. This pair of boots will be held for 30 days from date of report and unless otherwise directed, it will be placed in stock. Control data for boots issued collected on form, Addendum #1, and later transcribed to cards.
10 Oct	Coordinator, Test Boot Project letter HRK:dbg 4730 of 10 Oct 1972 to S-4, RTR transmitted Test Boot Project instructions, Addendum #2, and Platoon Rosters of recruits with test boots in Series 2117.
9 Nov	Coordinator, Test Boot Project letter HRK:dbg 4730 of 9 Nov 1972 transmitted new platoon roster for updating.
16 Nov	Mr. A. Wilson, Civilian Compound Technician, from Natick Labs and MGySgt KLEMM inspected about 50% of test boots in Series 2113. No conclusions were reached; however, excess wear of heels, hairline cracks in heels of boots with new higher abrasive compounds and excess wear of polyurethane foam heels; craking of polyurethane foam soles and the protrusion of metal support in the experimental Panama Chevron sole design was noted. This was the 58th day of the wear test for this Series.
20 Nov	A 20% sampling of Series 2117 test boots was noted. Excess wear of heels and hairline cracks in heels of boots with new higher abrasive compounds was noted. This was the 49th test day of the boots.
6 Dec	Series 2113 test boots were recovered (54 pair). Total test period for the Series was <u>78 days</u>. Standard replacement boots were issued.
13 Dec	Series 2117 test boots were recovered (56 pair). Total test period for series was <u>72 days</u>. Standard replacement boots were issued.

APPENDIX B

Compounding Materials

Materials (Trade Name)	Identification	Supplier Nos.
Rubber		
Hycar 1001	Butadiene-acrylonitrile copolymer	6
Hypalon 40	Chloro-Sulfonated polyetheylene	7
Paracril BJLT	Butadiene-acrylonitrile copolymer	16
Paracril 18-80	Butadiene-acrylonitrile copolymer	16
SBR 1502	Styrene/Butadiene	8, 16, 18
Taktene 1252	Oil-extended Cis-polybutadiene	20
Tylac 110 B	Butadiene-acrylonitrile copolymer	31
Tylac 121A-LV	Butadiene-acrylonitrile copolymer	31
Rubber Chemicals		
Altax	Benzothiazyl disulfide	6, 26
Arizona 208	Isooctylester of high purity tall oil fatty acid	4
Captax	2-mercaptobenzthiazole	26
Carbowax 4000	Polyethylene Glycol	35, 31
Cumar P25	Para coumarone-indene resin	1
Cumate	Copper dimethyldithiocarbamate	26
DOA	Di octyl Adipate	28, 33, 35
DOTG	Di-ortho-tolylguanidine	7
Durez 12687	Phenolic resin	11
EPC black	Easy Process Channel black	5, 12
Flexzone 3C	N-isopropyl-N-phenyl-P Phenylene diamine	16
Hi Sil 233	Hydrated Silica	18
Maglite D	Magnesium Oxide	
Methazate	Zinc dimethyldithiocarbamate	16
NBC	Nickel butyl carbamate	7
Neozone A	N-phenyl-alpha-napthylamine	7
Octamine	A reaction product of diphenyl	16
PEAC 617	Polyethylene AC 617	1
PER 200	Pentaerythritol	10
Petrolatum	Petroleum jelly	13
Philblack "O"	High Abrasion Furnace Black	5, 12
Plasticizer TP90B	High Molecular weight polyether	24
Sulfur		26

APPENDIX B

Compounding Materials

Materials	Identification	Supplier Nos.
(Trade Name)		
Rubber Chamicals (Cont'd)		
Sundex 790	High Aromatic Type Oil	23
Sunproof Jr.	Mixture of Selected Wales	16
SRF Black	Semi-reinforcing furnace Black	5, 12
Stearic Acid	.	28
Tetrone A	Dipentamethylene thiuram disulfide	7
Thermoflex A	P-P dimethoxy dipenylamine and 25% diphenyl-P-phenylene diamine	7
Zn O	Zinc Oxide	21

APPENDIX C

Materials Suppliers

Numbers	Suppliers
1	Allied Chemical Corp., Philadelphia, PA
2	American Cyanamid, Bound Brook, NJ
3	Arco Chemical Co., Philadelphia, PA
4	Arizona Chemical Co., New York City, NY
5	Cabot Corp., Boston, MA
6	B.F. Goodrich Chemical Co., Cleveland, Ohio
7	E.I. DuPont de Nemours & Co., Inc., Wilmington, Deleware
8	Goodrich Gulf Chemicals, Cleveland, Ohio
9	Goodyear Chemicals, Akron, Ohio
10	Hercules Powder Co., New York City, NY
11	Hooker Chemical Corp., Durez Plastics Div., Niagara Falls, NY
12	J.M. Huber Co., New York City, NY
13	Kuhne-Libby Co., New York City, NY
14	Marine Magnesium Products Div., Merck Co., Inc., Rahway, NJ
15	National Lead Co., New York City, NY
16	Naugatuck Chemical Co., Naugatuck, Connecticut
17	Neville Chemical Co., Pittsburgh, PA
18	Phillips Petroleum Co., Rubber Chemicals Div., Akron, Ohio
19	Pittsburgh Plate Glass Co., Pittsburgh, PA
20	Polymer Corp., Limited, Sarnia, Ontario, Canada
21	Saint Joseph Lead Co., New York City, NY
22	Sierra Talc and Clay Co., S. Pasadena, California
23	Sun Oil Co., Philadelphia, PA
24	Thiokol Chemical Corp., Trenton, NJ
25	Universal Oil Products, Des Plaines, Illinois
26	R.T. Vanderbilt Co., Inc., New York City, NY
27	Witco Chemical Co., Inc., New York City, NY
28	The CP Hall Co., Akron, Ohio
29	Hardwick Standard Chemicals, Akron, Ohio
30	Monsanto Chemical Co., Akron, Ohio
31	International Latex Corp., Dover, Deleware
32	Polymel Corp., Baltimore, MD
33	W.R. Grace (Hatco Chemical Div.), Fords, NJ
34	Marbon Chemical Div., Borg-Warner Corp., Washington, W. VA
35	Union Carbide Corp., Chemicals & Plastics, New York City, NY